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ABSTRACT

A study on sentence processing involving rehearsal, response initiation, and mental transformation required the subject to perform a secondary task concurrently with transformation of a sentence previously given. A secondary task interruption technique was used to allow inferences as to where the planning occurs by measuring increases in task time or pausing time. The primary question of interest was whether cognitive operations in terms of planning were carried out prior to the verbalization of the sentence or applied concurrently as the sentence is produced. The results support the contention that planning in terms of cognitive operations does take place prior to verbalization. The experimental task (transformations) involved lists from a pool of simple, active, affirmative, and declarative sentences together with their negative and passive transformations. The secondary tasks were generated on semantic and syntactic levels. It was found that the location of interruption is the most important variable in the length of secondary task performance time and that secondary task duration times increase with the difficulty of the transformation being made, but not differentially within location. Both location and transformation were found to affect pausing time; the initial pause location and the passive transformation contributed the greatest effect. (SW)

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LOCATION OF COGNITIVE OPERATIONS IN SENTENCE PROCESSING

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Introduction

Until recently research in experimental psycholinguistics has been greatly influenced by descriptive linguistics. The obvious inadequacies of surface structure to explain the competence of native language users in comprehending and producing speech encouraged proponents of a more nativistic and wholistic approach to both language comprehension and production. Given the added difficulty encountered by psychologists to explain language acquisition or production on a purely behavioral or empirical basis, biologically-oriented researchers have taken the position that language production and perception must be in harmony with the operating characteristics and the neurological processes of the human brain. This theoretical approach, then, changes the focus of attention from the surface structure and descriptive content of language to the establishment of analogies in general perceptual, motor and cognitive principles and the unity between these systems. Production and perception of speech in this context presupposes an underlying sequence of events coordinating the function of biological structure and the cognitive system toward the goal of planning and producing overt speech.

The rhythmic alternation between speaking and pausing has suggested to both linguists and psychologists that the hesitation pause is a significant indicator of cognitive planning for integration of the systems involved in producing language. In addition, and by analogy to well-documented research in motor skills, the complexity of the integration of the cognitive and articulatory anticipation required in production of speech has been of interest. A wholistic approach such as that of Lenneberg (1967) emphasizes the accommodation of known physiological and neural constraints intrinsic in the variation in firing of nerve fibers and muscle contraction. It is evident, asserts Lenneberg (1967), that the simplest sequence of events must require a hierarchical plan. In this plan, events are not contingent upon the occurrence of a prior event (i.e., the firing of another neuron), or the probability of occurrence of a previous

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letter or word, but are integrated elements within units of time often amounting to less than a second.

Since pausing is a phenomenon which occurs intermittently within and between sentences, the question arises as to whether sentences are formulated and planned as well as integrated during the initial pause prior to overt speech, within the verbalized sentence, or in both locations. The location and duration of pauses vary idiosyncratically with individuals, type of material involved, task requirement, and the ongoing state of the individual. The research of Goldman-Eisler (1968) and others has supported the conclusion that pauses are not always coincidental with grammatical breaks. There are three main purposes for gaps or pausing in overt speech. The first is the use of pausing as a tool for emphasis in social communication. The second is to regulate expiration and inspiration of air in order to facilitate further articulatory movements. The third purpose for pausing is assumed to be cognitive planning. Economically, breath pauses will occur simultaneously with hesitation pauses. Normal, fluent speech is well controlled and has all the manifestations of a highly-practiced and rhythmic motor behavior. Asynchrony occurs during a shift of attention, during periods of high cognitive activity or as a result of lack of verbal facility, or cognitive overload. Pausing also reflects the need to assemble a syntactic or semantic unit which is difficult. Asynchrony in speech and pausing, then, is symptomatic of the creative act of generating a new structure.

Goldman-Eisler (1968) conceives of two stages of speech generation: the semantic aspect which is the conception of content to be verbalized; and syntax, the linguistic and phonetic execution of the internal formulation in a smooth, serial ordering of elements. She proposes that syntactic ordering is on the level of a skill or a pre-planned, automatic pattern. Therefore, fluent production of speech is dependent upon the habitual use of various types of syntactic ordering and reflects the degree of efficiency of the speaker. Such lack of verbal skill or complexity of decision making in restructuring input or incorporating difficult semantic content presumably would be reflected in longer pausing prior to or within overt speech. Recent research has suggested that the duration of the initial pause is correlated with difficulty in semantic abstraction and unpracticed or newly-combined syntactic structures (Rochester, 1973). Interpretations, changes, or extensions in meaning require a greater degree of attention to semantic decisions prior to speaking. In fluent, practiced, conversational speech, lexical choices would be predetermined also, while in speech which is both semantically more complex and less habitual for the individual, lexical choice may be more

difficult and require additional time made within the verbalized sentence.

Fluent speech has been defined as those passages without noticeable gaps or with hesitations amounting to less than 30 percent of the total of both speaking and pausing time (Henderson, 1966). It is possible, therefore, that a given amount of overt speech requires a proportional amount of pausing in which internal cognitive preparation is carried out. The proportion of pausing to speaking should vary then within linguistically-defined units in accordance with their difficulty.

According to Chomsky's theory (1965) of a generative grammar, transformations in the form of varying types of operations are applied to and convert the representations in deep structure to surface structure. Assuming that one or more operations must be carried out on the kernel sentence, that these operations vary in difficulty and are additive, the time for performing the operations would be reflected in pausing time either before or within the verbalized sentence. While research on the psychological validity of the operations presumed to be performed in transformations has been inconclusive, one of the earlier studies by Miller and McKean (1964) supported a conclusion of reasonably large and linearly-increasing times correlating with numbers of operations required for transformation. Such operations require attention to the central capacity to a greater or lesser extent depending on the size and difficulty of the transformation (Posner, 1965).

Based, then, on the concept of the human being as a limited capacity information processing system, the allocation of the capacity can be varied at will in accordance with the demands of the task. The capacity which is limited is that of the central cognitive structure to engage in one or more effortful operations of the same nature simultaneously. It is presumed that the central capacity is normally resistant to intrusion at the time it is engaged in an effortful operation. In other words, the central capacity is refractory or resistant to the handling of other incoming signals or tasks which require attention while it is engaged in a similar operation resulting in queuing of signals. Sentence processing in the present research requires three basic tasks: rehearsal, response initiation and mental transformation. The rationale of this study is to require the individual subject to perform a secondary task concurrently with transformation of a sentence previously given. Assuming that two operations of the same nature cannot be performed simultaneously without increasing the time for one or both, or making time in the form of additional pausing before or within the sentence, the present study has used a secondary task interruption

technique designed to allow inferences as to where the planning occurs by measuring increases in task time or pausing time. Specifically, the following sequence of organization is suggested. During the initial pause, a generalized, semantic set is invoked together with the entire structural ordering (the syntactic plan) of the sentence. Articulation is planned and integrated according to the syntactic structure. There are, then, two types of organization inferred, semantic and syntactic, each occurring on two levels. One level is cognitive planning, both semantic and syntactic; the other level is execution of the plan, lexical choice and temporal ordering.

There are four conditions which could be combined in various ways during the sentence transformation:

1. Semantic meaning which is easy and fluent.
2. Semantic meaning which is difficult and unpracticed.
3. Syntactic order which is easy and fluent.
4. Syntactic order which is difficult and unpracticed.

These combinations might be idiosyncratically altered by individual facility and efficiency in language skills. Since sentence transformation is considered to be primarily a semantic change, the operations performed to transform a sentence from a simple, active, affirmative, declarative to a negative or to a passive represent varying levels of semantic operational difficulty. Syntactic difficulty is contributed by the need to reorder the subject and object in sentences containing either embedded or right branching clauses.

The following hypotheses, then, are those to be explored:

1. Cognitive planning (either semantic or syntactic or both) occurs prior to verbalization of the sentence during the initial pause; alternatively, planning occurs concurrently during syntactic breaks.
2. The ratio of pausing to speaking within the cognitive unit (the sentence or idea) varies with the difficulty of the transformation to be made.

Decisions or inferences for or against these hypotheses would be based on the evaluation of differences in time required for performance of the secondary tasks as well as differences prior to and within the sentence in hesitation pauses.

Method

Experimental Design

Factors Studied

Reaction times for both tasks and pauses as they were affected by the following three factors were studied: first, the primary task or type of sentence transformation to be performed; second, the location of the interruption of the transformed sentence, either during the initial pause before verbalization or within the transformed sentence; and third, the type of secondary task to be performed, either semantic or syntactic. This design resulted in a three factor analysis of variance with repeated measures on all three factors.

Three types of transformations were made in both directions: SAAD (simple, active, affirmative, declarative) to SAAD (control), SAAD to negative and reverse, SAAD to passive and reverse. No transformations were made to passive negative or reverse.

During the primary task, the transformed sentence was interrupted in two locations, during the pause immediately after the instruction and prior to verbalization (the initial pause), or during the verbalization of the transformed sentence (within sentence).

There were three secondary task conditions, an interruption with no secondary task performed (control), an interruption with a semantic secondary task, and an interruption with a syntactic secondary task.

Subjects

During the running of pilot subjects, it was found that those subjects who had not previously mastered grammar, particularly the passive, at some earlier time, required too many training trials to perform competently. It was decided that since learning was not the subject of the study, volunteers would be requested from classes in psychology, sociology and English. Twenty-four volunteer subjects were obtained.

Subjects were required to commit themselves to completion of two sessions each requiring one and one-half to two hours.

Materials and Procedure

Materials

Experimental task (transformations). Lists were compiled from a pool of 144 SAAD (simple, active, affirmative, declarative) sentences together with their negative and passive

transformations. Complexity of the sentences was increased by inserting an embedded clause, or adding a right branching clause each having exactly the same internal structure. The numbers of these embedded and right branching sentences were balanced within conditions. All sentences were 12 to 15 words in length.

Two blocks of 72 sentences were presented. Within each block of 72 sentences, three subsets of 24 sentences were devised to coincide with each of the three types of transformations: The first subset of 24 sentences consisted of SAAD into SAAD (repeat-control), SAAD into Negative, and SAAD into Passive. The second subset of 24 sentences was Negative into SAAD, Negative into Negative, and Negative (Active) into Passive. The third subset of 24 sentences was Passive into Passive (repeat-control), Passive into SAAD, and Passive into Negative (Active). Each original subset of 24 sentences was further divided into 12 sentences, half of which were interrupted in the Within Sentence condition and half in the Initial Pause. The 12 sentences for each interruption condition were further subdivided into six sentences for a no-task control interruption and six for secondary task interruption. Within each group of six sentences right branching and self-embedded sentences were balanced.

The presentation order of the 72 sentences was randomized within each blocked presentation. No two sentences were alike either within or across blocks for any subject. Lists of sentences were counterbalanced for order of presentation across blocks.

Secondary task (semantic or syntactic). The secondary tasks used were generated on two levels, semantic and syntactic. The performance of each secondary task was signalled by a discriminably different stimulus, a red light for the semantic task and a green light for the syntactic task. A white light was used to signal the no-task interruption. The subjects were instructed prior to each block of tasks what the required response was to the stimulus light.

Within each block of 72 sentences, the secondary task was different. In addition to the control interruption condition with no task performed which occurred in all locations in both blocks of sentences, the first block of sentences was interrupted in the secondary task condition with a semantic task. The second block of 72 sentences was interrupted with a syntactic task condition. The presentation order of the blocks of 72 sentences and tasks was counterbalanced.

During each block of 72 sentences, the subject had in front of him three decks of cards: one deck of cards (36) coincided with the signal light (white) for the no-task

control condition which the subject acknowledged by picking up the blank card, turning it over, looking at it, and returning it to the bin. The second group of 36 cards was in the box below the signal (red) for the semantic task, and the third group of cards was under the signal light (green) for the syntactic task. The blank deck was used in both blocks for the control; only the appropriate deck, either semantic or syntactic, was used during the first block; the opposite deck was used during the second block.

The semantic task was as follows: On the face of the cards were typed three words, such as "Washington, New York, and Los Angeles." The subject was to respond with the word representing the superordinate category of the words such as "major cities." The words and categories were compiled from Battig and Montague (1969). After giving the category name, the subject then continued transforming the original sentence.

The syntactic task was as follows: Before the subject was placed a second deck of cards (36) under the green signal light. When these cards were turned over, three groups of numbers showed on the card. For instance, 734, 321, and 598 were typed on the card and the subject was required to place each group of three numbers in the proper ordinal position and respond aloud. The subject then proceeded with the sentence transformation. The number groups were made from the Table of Random Numbers.

As indicated previously, the secondary task and sentence list were counterbalanced across blocks to avoid order effects. To summarize, the first block was interrupted in both locations (initial pause and within sentence) with no-task control performance and with performance of the semantic task. The second block of 72 sentences was interrupted with no task (control) to be performed and with a syntactic task. No sentence was interrupted more than once.

Training Trials

Each subject received a training session to a criterion of one errorless trial on performing 24 sentence transformations with no interruptions prior to the actual experiment. Those subjects not able to attain the criterion in three trials (24 sentences each trial) were dropped out. This was to insure that the response time differences could be assumed to be due to difficulty in processing rather than to differences in competence, or learning.

Procedure

Each subject was presented with pre-recorded sentences by means of playback on a Wollensak reel-to-reel tape recorder. Each subject was presented the training trials which were self-paced. After completion of the training trials, a short rest period was given the subject after which the experimental session was begun. At this time all responses were recorded on magnetic tape as well as being recorded by tracings on thermal sensitive chart recording paper. The general sequence of events was as follows:

1. Training trials.
2. Rest period.
3. Subject begins experimental task (72 sentences).
4. Subject repeated sentence twice after hearing it and was corrected if necessary.
5. Memory drum was activated and instruction for transformation appeared in the window.
6. Subject transformed sentence.
7. At the end of the 36 sentences, a rest period is given.
8. Subject resumes task and completes last 36 sentences.
9. After second session of 72 sentences, subject was debriefed.

Two different sequences of events occurred. The sequences were identified by indicating the location of the interruption, either the IP sequence (initial pause), or the WS sequence (within sentence). The order of events within sequences is as follows:

IP (Initial Pause)	WS (Within Sentence)
1. Playback of original sentence. Experimenter turns recorder on.	1. Same
2. Subject repeats original sentence two or more times as needed. Here experimenter activates chart recorder and selects proper circuit on control panel.	2. Same
3. Memory drum triggered by experimenter.	3. Same
4. Instruction appears for one second in window of memory drum.	4. Same

IP (Initial Pause)	WS (Within Sentence)
5. Signal light switched on by experimenter immediately upon MD step.	5. Subject beings to speak.
6. Subject picks up card and performs secondary task.	6. Experimenter turns on signal for secondary task.
7. Subject turns off signal light when task completed.	7. Subject picks up card and performs secondary task.
8. Subject continues with transformation.	8. Subject uses switch to turn off signal light when secondary task is completed.
	9. Subject continues with transformation.

Here the experimenter turns off chart recorder and indicates errors, if any, on tape.

Equipment

Playback tape recorder. The playback of the original sentence previously recorded was accomplished by using a reel-to-reel Wollensak tape recorder. The sentences were pre-recorded on magnetic tape by a professional reader. Two separate reels were used; each began with 24 training sentences. The training sentences on the first reel were followed by 72 sentences comprising Block I. The 24 sentences on the second reel were followed by the 72 sentences comprising Block II.

The time interval between sentences was controlled manually by the experimenter who also manually turned the recorder on and off.

Chart recorder. An MFE Model 25 Chart Recorder was used. The occurrence of three events was traced on heat sensitive dual track paper, divided into 50 mm. each, a total of 100 mm. wide. The recorder was set to run at 25 mm. per second so that one inch was the equivalent of one second.

Three event pins were used each indicating the onset, duration, and offset of an event: The activation and duration of exposure of the instruction on the memory drum, the presence or absence of the signal light, and the presence or absence of verbalization by the subject were each traced separately on the recording paper. The duration of these events was measured subsequently by a ruler divided into tenths of an inch so that each 1/10 inch was the equivalent of 1/10 of a second.

Memory drum. Instructions were presented by a modified Stowe #459E memory drum. The modification allowed the experimenter to control the onset of the exposure by a push button on the experimenter's control panel. The duration exposure for one second was automatically preset.

Control panel. The control panel in front of the experimenter contained a power switch to activate the logic sequences, three switches for selection of the proper color signal light, and a push button to control the memory drum.

Subject panel. In front of the subject beneath the window in the memory drum appeared a panel with three different colored signal lights. Below each signal light was a bin in which the appropriate deck of cards was kept. At one side of the bins was a push button which allowed the subject to turn off the signal light when the secondary task was completed. Also at one side was mounted a stationary microphone on a gooseneck support so that it could be adjusted for each individual subject. The microphone was a Sony F-255 microphone.

Results and Analysis

The primary question of interest was whether cognitive operations in terms of planning were carried out prior to the verbalization of the sentence or applied concurrently as the sentence is produced.

The results support the contention that planning in terms of cognitive operations does take place prior to verbalization.

The two dependent variables, task time and pause time, were analyzed separately in a 2 x 3 x 3 analysis of variance with repeated measures on all three factors. From the raw data, individual mean times were calculated. Separate analyses were then carried out on mean task times, mean pausing time after tasks, ratio of pausing to speaking (P/P+V), and frequency of errors.

Goldman-Eisler (1968) found that breath pauses in fluent speech are as short as .25 seconds. To obtain this degree of accuracy, measurements were made of tasks and pauses to 1/10 second, for each of the following variables from each transformed sentence.

Initial Pauses (IP): Time elapsed between presentation of the transformation instruction to the beginning of verbalization.

Secondary task time (ST): Total time required to perform the semantic or syntactic task after verbalization stops to the point in time where the subject turned off the signal

light indicating completion of the task.

Control (no task): Total time elpased from verbalization off, picking up the card, looking at the card, returning the card to the bin, and turning off the light.

Pause time (after ST or Control): Time elapsed from point at which subject turned off signal light indicating end of secondary task or control to beginning of verbalization.

Speech time: Total time required to speak the transformed sentence less secondary task time.

Pause to speech ratio (P/P+V): Ratio of pausing to pausing plus speaking (after interruption) in each transformed sentence (Henderson, 1965).

Task Duration Analysis

Total elapsed time for the performance of each task and the control was taken from the tracings on the recording tape. Mean task duration times for each individual were then calculated from the raw data and the rest of the analyses were carried out on these individual mean times. The intent was to reduce variability within subjects, and to assure that treatment effects would be significant only if strong.

In addition to the previously-described semantic and syntactic tasks, the control condition required the subject to perform the motor aspects of the other two tasks without the cognitive aspects, that is, to respond to the signal light, pick up a blank card, look at it, return it to the stack, and turn off the light. Before the experiment, an attempt was made to equate the difficulty of the two tasks insofar as inferred cognitive operations were concerned. The actual performance times were different. Each task was composed of three items. In the case of the semantic task, each of the items was a word which had to be compared with each of the other two words to abstract the common criterial attributes to arrive at the superordinate category. In the case of the syntactic task, three groups of three numbers comprised the display. Each of the groups had to be rearranged ordinally and reported in the correct order, one group at a time. Throughout the experiment, the semantic task was always accomplished more quickly than the syntactic task. This was true even though each task had one item which had to be compared successively with two others before responding. However, one (the syntactic task), being a serial ordering task required time, while the other (the semantic task) required attention. The relative mean difference between the tasks remains constant, but the

absolute differences vary according to treatment effects.

At the outset, an overall analysis of variance was performed on the mean task duration times. Significant F ratios were obtained for the following effects: Location, $F(1,23) = 175.43$; Tasks, $F(2,46) = 273.81$; Transformations, $F(2,46) = 13.64$; Transformations within Tasks, $F(2,92) = 4.59$; all $p < .01$; and Tasks within Location, $F(2,46) = 9.01$; $p < .05$.

Location. The F ratios substantiate the significant difference between the two locations. Any interruption in the Initial Pause condition results in longer task duration times for both tasks and the control when compared to the Within Sentence interruption condition. The overall mean performance time for all tasks (including the control) in the Initial Pause condition is 6.17 seconds, 1.15 seconds longer than the mean time of 5.03 seconds in the Within Sentence condition. This effect of location of interruption is consistent throughout the analysis; all tasks taking longer to perform in the Initial Pause condition.

Tasks. As indicated previously, there is an intrinsic difference in time for performing the two tasks, semantic and syntactic. Table 1 summarizes the mean differences. The mean time for performance of the semantic task is 5.64 seconds as opposed to 7.69 seconds for the syntactic task across conditions. Since most of the effect in the ANOVA was contributed by comparison of tasks with the controls, t tests were performed to determine differences between the semantic and syntactic tasks both within and between conditions, following the significant F ratio for tasks within location. The difference in the semantic task when performed in the Initial Pause condition versus the same task performed in the Within Sentence condition was significant, $t(71) = 12.74$; $p < .001$.

The same test on the syntactic task comparison between conditions was also significant at $p < .001$ ($t(71) = 8.86$), substantiating the important effects of place of interruption on the secondary task performance time.

As expected, within each condition, the two tasks differed significantly from each other primarily because of the consistent time difference previously discussed; for the Initial Pause condition the difference between the semantic and syntactic task was $t(71) = 11.98$, and for the Within Sentence condition, $t(71) = 15.33$, both $p < .001$.

In summary, the greatest effect on task performance time is contributed by the place of interruption with the secondary task. The interpolation of either task in the Initial Pause

condition disrupts processing and results in longer task performance times (including the control).

Transformations. The significant effects involving transformations resulting from the analysis of variance occur in two areas: The transformations differ significantly from each other, $F(2,46) = 13.64$; and they interact with tasks differentially, $F(2,92) = 4.59$, both significant at $p < .01$. Table 1 summarizes the mean times for transformations. These means are consistent with the nonsignificant F ratio for interaction between location and transformation. Transformations do interact with tasks across interruption location, however, to increase the mean task performance time according to the difficulty of the transformation ongoing at the time the task is interpolated. (See Table 2.) In each task, the performance time increases in the following transformational order: SAAD < Negative < Passive, except in the control where there is little change in the performance time. The greatest difference in means, however, occurs in the semantic task condition where the difference between SAAD and Negative is .21 as opposed to .10 in the syntactic task; the difference between the SAAD and Passive is .74 in the semantic task as compared with the .17 in the syntactic task.

In summary, the location of interruption is the most important variable in the length of secondary task performance time, mean time being significantly longer in the Initial Pause condition. Secondary task duration times also increase with the difficulty of the transformation being made at the time, but not differentially within location. The greatest variability in the secondary task time related to the transformation occurs within the semantic task.

Pause Analysis

One of the important assumptions in this research is that hesitation pauses, or pauses generally are indicative of the need for cognitive processing; changes in distribution, duration and ratio of pausing to speaking time are symptomatic of the overload on information processing capacities of the organism.

Based on the concept of a limited capacity processing system, overload may be reflected not only in the increase in task duration time as confirmed in the previous analyses, but also the pausing time after the task. Task duration time and pausing time may increase or decrease, or both may occur according to task difficulty and proficiency of the individual. While the measure of task time is significant in showing the nature of the processing at the time the secondary task is interpolated, the amount of pausing after the interruption is the most significant measure to indicate the depth

of the interruption and the consequent need for reorganization.

As previously indicated, Goldman-Eisler (1968) found that respiratory pauses in fluent speech are as short as .25 seconds, and that breath pauses and planning pauses are often coincidental in speaking. It cannot be assumed then that only longer pauses include cognitive operations. Therefore, all pauses exceeding .25 seconds were included in total pausing time.

Mean pausing time was calculated for each individual from the raw data for each of the measures indicated previously, namely, the initial pause, and the amount of pausing after the interruption with the secondary task or control. All analyses then were calculated on these individual mean pausing times.

The "initial pause" is the elapsed time between the subject's comprehension of the instruction concerning the required transformation, and the beginning of verbalization of the transformed sentence. This pause is randomly interrupted with the performance of the secondary task (semantic or syntactic) or the control (no task), prior to the verbalization of the transformed sentence. "Initial pause" is used therefore to denote the place of interruption as well as the pause which is interrupted.

The "within sentence" pause which is important is the pause which follows the interruption of the required transformation after the secondary task or the control is performed. The phrase "within sentence" is also used to denote the location of the interruption.

In the Within Sentence condition, the interruption with the signal to perform the secondary task or the control was timed to occur after approximately two or three words into the sentence transformation. Individual differences in speech rates caused a slight variation in location of interruption. The total amount of speech time prior to the interruption in the Within Sentence condition was not included in the total speech time for the Within Sentence condition, nor was the pause preceding the transformed sentence included. The only significant pause in this condition was that following the interpolated task.

An overall analysis of variance based on mean pausing time resulted in the following significant effects: Location, $F(1,23) = 36.88$; $p < .01$; Tasks, $F(2,46) = 22.15$; $p < .01$; Transformations, $F(2,46) = 7.52$; $p < .01$; and Transformations within Location, $F(2,46) = 8.48$; $p < .01$.

Location. There was a pronounced effect on mean pausing time following tasks attributable to location. All pausing in the Initial Pause condition was longer than pausing occurring within the sentence. Even the pausing after the control shows the differential effects of location. The mean pausing time for the Initial Pause condition was 2.57 seconds as opposed to 1.52 seconds for the Within Sentence condition. The fact that the pause after the syntactic task is shorter than the pause after the semantic task within the Initial Pause condition supports the conclusion that the effects of location cannot be attributed only to the length of the interruption.

Tasks. Results of t tests performed on the differences in mean pausing time after each task performed in the Initial Pause versus the Within Sentence condition resulted in significant differences at each task level between conditions. The pause following the performance of the semantic task in the Initial Pause condition exceeded the pause after the semantic task in the Within Sentence condition by 1.35 seconds, and was significant ($t(23) = 3.72$) at $p < .01$. The pause following the performance of the syntactic task in the Initial Pause condition exceeded the same pause within the sentence by .91 seconds ($t(23) = 3.11$) and was significant at $p < .01$. Even the pausing time after the control (no task) was greater by .99 seconds in the Initial Pause condition, $t(23) = 4.76$; $p < .01$. Although it may be observed that within the Initial Pause condition, pausing time following the semantic task is longer than the pause following the syntactic task by .33 seconds, this difference is not significant.

Transformations. In the previous task time analysis, transformations had interacted with tasks across interruption conditions. The semantic task performance time reflected this interaction to a greater extent. In the case of the present analysis of pausing time, there is no variation within either task due to transformations. The significant effect of transformations on pausing time is within the location of the interruption. This effect is significant in the ANOVA, $F(2,46) = 8.48$ at $p < .01$. Table 4 summarizes the mean pausing times for pauses grouped by the transformation after which they occur and according to location. Pausing time during transformations is affected by the interruption location. Pausing is longer after all transformations in the Initial Pause condition when compared with the Within Sentence condition. This finding suggests that transformational processing occurs primarily in the Initial Pause condition rather than within the sentences. Tests made comparing the mean value of the SAAD plus Negative pausing time with the Passive resulted in a significant value, $t(71) = 3.35$; $p < .001$, in the Initial Pause condition. The three transformations did

not differ significantly from each other in the Within Sentence condition.

In summary, the main variable affecting pausing time is the place of interruption. All pauses in the Initial Pause condition were longer than those in the Within Sentence condition. The relative differences between task related pause length remain the same between conditions. Examination of the pause times within conditions shows that the pause after the semantic task is longer than the pause after the syntactic task. There is a reversal of the effect found in the task duration analysis, but the difference in this case is not statistically significant. Task related pauses increase in the following order: < Control < Syntactic < Semantic.

Within interruption conditions, transformations differentially affected the pausing time. Within the Initial Pause condition, the pausing time during the Passive transformation is significantly longer than the mean of the other two transformations. There is, however, no significant difference in the pauses during transformations within the sentence.

The conclusion is then both location and transformation affect pausing time, the initial pause location and the passive transformation contributing the greatest effect.

Pause to Speech Percent (P/P+V)

It may be recalled that Henderson (1965) had concluded that while the ratio of pausing to speaking is quite individualistic, in general, the ratio for fluent passages in spontaneous speech to be categorized as rhythmic is approximately 30%. Pausing in fluent speech may include percentages of pausing from close to zero up to 30% varying according to individual differences. This ratio was used by Henderson to evaluate whether passages were fluent or rhythmic. This was not a mean pausing ratio, but an arbitrary point beyond which the amount of pausing indicated cognitive activity.

It was assumed in the present research that the only relevant aspects of the transformed sentence in either interruption condition were those portions which followed the performance of the secondary task and the subsequent pauses. Only those measurements were used to make comparisons. In the Initial Pause condition, of course, the total pause after the task and any subsequent pausing after verbalization began were used. In the Within Sentence condition, only that portion of the pausing and speaking which followed the interpolated task was used. Since measures were taken on a complete sentence in one case

(initial pause), and only the portion which followed the interpolated task in the second (within sentence), no attempt was made to compare them on a one-to-one basis. Instead, mean pausing ratios were calculated within each condition for each individual from the raw data. Table 5 displays these ratios. The individual ratios were then transformed into arcsin values, and t tests calculated to determine if any ratio departed significantly from the control ratio and from each other within interruption condition. Comparisons were also made between conditions. Table 6 summarizes these values.

In the Initial Pause condition, each of the tasks, semantic and syntactic, differed significantly from the control, but did not differ significantly from each other, $t(23) = 6.03$, $t(23) = 4.87$, both $p < .05$.

In the Within Sentence condition, the same result was found. Each of the tasks differed significantly from the control, but did not differ significantly from each other, $t(23) = 2.85$, $t(23) = 3.44$, both $p < .05$.

Comparisons were also made on the ratios between conditions. The significant result was the comparison of the pause ratio after the performance of the semantic task in the Initial Pause condition versus the Within Sentence condition, $t(23) = 1.75$, $p < .05$. The ratio of pausing to speaking is increased significantly, then, over the 30% ratio when the semantic task is performed in the Initial Pause condition. This is another conclusion which suggests that transformational processing which is essentially semantic in nature, occurs primarily in the Initial Pause condition.

The interesting fact to note about these analyses is that even using a different task and a discrete linguistic unit rather than discursive material, the control condition shows the same ratio as that suggested by Henderson (1966).

Error Analysis

Errors were classified as indicated in Table 7. There were 144 sentences to be transformed by each subject; 72 sentences in each experimental session. In all, 3,456 observations were taken over a total of 24 subjects. Out of this number, 385 errors occurred which represented 11% of the total observations. This is truly remarkable in view of the length of the experimental session (1½ to 2½ hours) and the obvious effort and attention required of the subjects. While there was some individual variation, these 24 subjects represented a high level of language proficiency.

To evaluate the effect of tasks on the subsequent errors involved, errors were grouped according to the task condition, either semantic or syntactic, in which they appeared, and are summarized in Table 7. On the presumption that with no effect of tasks, the errors would be distributed on a completely random and chance basis, the observed and expected values were tested as to goodness of fit and yielded a non-significant Chi Square value. The hypothesis that errors were distributed by chance between the two task conditions was accepted with the further inference that tasks had no effect on errors.

Since the important variable in this study is the location of interruption with the interpolated task, the errors were regrouped according to the frequency with which they occurred within each interruption location. Chi Square was again calculated to test the goodness of fit to a chance distribution. The test yielded a significant Chi Square value of 34.72; $df = 5$; $p < .005$, enabling a rejection of the hypothesis that errors were randomly distributed between locations. Table 8 summarizes the frequency of errors within each location. The 217 errors in the Initial Pause condition represents 56% of the total number of errors (385). Within this condition, omissions of words, especially adjectives, and changes in meaning were the largest categories. The 168 errors in the Within Sentence condition represent 44% of the total number of errors which occurred. Changing the order of adjectives, and starting twice with the transformed sentence accounted for the largest number of errors.

The error classified as "two starts" occurred in the following way. In the Initial Pause condition, after the interpolated task the subject would begin the transformed sentence. At the point when the subject got to the first noun or verb, the subject would realize that the relative clause was to be inserted in the case of the Passive transformation. If this occurred in the SAAD or Negative, a correction was needed. The subject would then stop immediately and start the sentence over from the beginning. In the case of the Within Sentence condition, this phenomenon occurred most often in the following way: The subject would begin the sentence incorrectly, be interrupted with the secondary task, and after performing the task, would start over. The verbalization after the interruption then would be correct. This type of error was associated primarily with the performance of those subjects who were less fluent and less knowledgeable of the Passive transformation. Goldman-Eisler (1968) evaluated this type of error as manifesting the need for auditory feedback to make corrections and comparisons of output with an unpracticed schema. These errors occurred most often in the case of the Passive transformation since many of these sentences required the reversal

of subject to object, and additionally, the change in order of the relative clause.

To evaluate the effect of transformation on the distribution of errors, observed frequencies were compared with estimated frequencies based on the assumption of errors distributed equally between the transformations. In the Initial Pause condition (see Table 8), the significant Chi Square value was 35.42, $p < .001$, allowing the conclusion that transformations did significantly affect the frequency of errors within the Initial Pause condition. The same conclusion was reached after testing the frequencies in the Within Sentence condition based on a Chi Square value of 48.39, $p < .001$ (see Table 8). In both interruption locations, the frequency of errors was greatest in the Passive transformation.

The conclusion is then again that the place of interruption with the interpolated secondary task is the most important factor affecting errors, with the initial pause being the most sensitive location. Tasks do not affect errors substantially, but transformations ongoing at the time of interruption do affect error, with the greatest number occurring in the Initial Pause condition during the Passive transformation.

Discussion

General Conclusion

This research was contemplated in order to obtain data supporting a decision as to whether or not planning and organization take place prior to the overt speech or concurrently during speaking. The results substantially support the conclusion that cognitive activity occurs prior to verbalization.

In arriving at this conclusion, it was necessary to specify the results which would document a clear differentiation between the two models. In either location of interruption, organization could take place either sequentially in stages, or simultaneously. The stage model would assume some selective interference reflected in increased errors in either the task or the transformation, or alternatively, that either the task or the pause following it would increase. If cognitive planning occurs simultaneously in terms of semantic and syntactic planning, there should be a systematic increase in performance time when both operations are occurring at the same time. Interaction effects would be expected with either one or both tasks according to the location where they occur, either the initial pause or within the sentence.

The secondary tasks were devised to require decision making or attention from the central cognitive processor. Depending upon the size of the transformation, more or less attention would be required to perform the appropriate operations.

All of the analyses show a significant effect of interruption location on both task time and pausing time, as well as the relationship between the two. Since all time measures were longer in the Initial Pause condition as opposed to the Within Sentence condition, my conclusion is that cognitive operations in terms of planning and organization occur during the initial pause rather than within the sentence.

Some might challenge this conclusion on the basis that other phenomena might explain the strong effects during the Initial Pause condition. These possible arguments, and the reasons why they are rejected, will be discussed.

Since there was an intrinsic difference between the semantic and syntactic tasks, it might be argued that the significant task effects could be entirely attributable to length of interruption. A closer examination of the results indicates that there was also a significant increase in the duration time for the control (no task) condition. The assumption was made that no cognitive part of either task was included in the control. However, the significant effect of place of interruption, namely, the initial pause, was manifested in increased duration times for the control, both in terms of the task measurement, and the pause measurement. Since all three task conditions took different lengths of time to perform, and all three show an increase in the Initial Pause condition, length of interruption alone cannot be the explanation for the significant effect in the initial pause.

Another argument which might be raised to controvert the present conclusion that cognitive planning occurs primarily during the initial pause because of the increased time measures is that active rehearsal of either the original sentence or the instruction has been interfered with. Two points are against this explanation. First, there were very few errors in recalling either the original sentences or instructions. Secondly, the same tasks were used in both conditions and were carefully counterbalanced for presentation. If the task or the interruption caused loss of time or attention for active rehearsal, the same effect should have occurred within the sentence. Therefore, the argument of interruption of rehearsal and loss of short-term memory is also rejected.

Reaction time studies have consistently resulted in the conclusion that with increasing numbers of alternatives, decision-making time is required by the organism. Both

numbers of operations and difficulty of operations affect reaction times to problem solving. This is the explanation which is most consistent with the approach that planning and organization take place prior to the sentence, and with the data.

Another question which should be raised is whether planning is occurring in both locations. If both semantic and syntactic planning were occurring in the initial pause and within the sentence, there should have been an equal delay, and not the strong effect of location which did occur. If only one type of planning was occurring in either place, a selective interference or increase in duration time for the appropriate task would have been the result. Since both tasks took longer to perform and the pauses following were longer in the Initial Pause condition, the remaining conclusion is that cognitive activity in terms of decision making takes place prior to the sentence.

Nature of the Planning

The semantic task was devised to require attention from the central cognitive processor. Since transformations are semantic in nature and of varying levels of difficulty, the semantic task would increase in performance time according to the difficulty of the transformation ongoing at the time of the interpolation. The two operations would conflict. If transformations are occurring within the sentence and the semantic task is interpolated, the result would be longer performance time for the task, and greater difficulty returning to the execution of the sentence after the interruption. The same type of inference could be made for the syntactic task.

In all of the analyses, there was a significant effect of location of interruption reflected in longer task duration times for both tasks, and longer pausing time after the tasks, in the Initial Pause condition as opposed to the Within Sentence condition. Since there were no controls to prevent subjects from storing the incoming information required by the secondary task, holding it while completing the transformation, and then completing the secondary task, or vice versa, there is no way to determine whether the two were processed serially, or whether some simultaneous processing occurred. Since there is an overall difference in semantic task time across locations which varies with difficulty of transformation, but not within location, task time cannot be used to pinpoint the nature of the processing.

Two other results, however, do suggest that semantic processing occurs primarily in the Initial Pause condition. In the pause analysis is found a significant effect of

transformations within location; that is, in the initial pause. Since transformations are semantic in nature, logically, it would follow that semantic processing is occurring in the Initial Pause condition. Pausing is also longer after the semantic task in the Initial Pause condition, although not significantly so. Another result which suggests this conclusion is that the ratio of pausing to speaking after the semantic task is significantly different in the Initial Pause condition as opposed to the Within Sentence condition. If we espouse a model of a limited capacity organism, the assumption would be that both the difficulty and quality of the interpolated task affect the amount of central capacity allocated. Semantic processing is an effortful process. Longer task times and longer pausing after the semantic task may be symptomatic of the quality of abstraction occurring.

The error data do not clearly support either kind of processing, but consistent with the other analyses, do show an effect of location. Within interruption condition, the Passive transformation accounts for the largest number of errors. Those in the Initial Pause are greater than the same error in the Within Sentence condition. Although tasks did not affect the errors substantially, the error data are consistent with the pausing data which showed a significant effect of transformations within location. Since the Passive transformation requires the greatest semantic change, the results suggest but do not confirm that semantic processing occurs primarily in the Initial Pause condition.

While none of the results alone is definitive, taken together, they are highly suggestive of the conclusion that semantic planning occurs primarily before the spoken sentence. Supportive of this is Butterworth's (1975) study which found that in discursive speech, pauses increase prior to semantic or idea units rather than between breaks. Both of these findings are consistent with Goldman-Eisler's (1968) data indicating that as numbers of sentences increase, the pauses between sentences and before coordinate clauses increase, since they are in fact constrained by previous semantic content rather than syntactic order.

Goldman-Eisler's primary contention that syntactic structure is automatic and pre-programmed prior to verbalization must also be analyzed in the light of present data.

> The conception of ready-made sentence schemata, models of sentences or modules implies that they are selected in one piece so to speak, that they are not constructed from individual lexical

> elements--and this would account for the fluency of speakers irrespective of their complexity, in the same way as efficiency in mass production is a matter of use of prefabricated units . . .
>
> What seemed to take time was choosing a different schema from the one presented, a complex process involving the rejection of the structure as received, the decision to deviate from it and the choice of an alternative syntactic form . . . (Goldman-Eisler, 1968, p. 128).

If some comparison or decision were not necessary in regard to rejection of the original schema or choice of an alternative form, there would have been no increase in task time between the two locations. The syntactic task duration would be the same in both conditions; or, if the decision concerning the three alternatives (syntactic form) was made during the sentence, this decision time would have been reflected in the task or pause time. Both the SAAD and Negative had very little change in syntax, but the Passive transformation required not only reversal of subject to object, but also re-ordering of the relative clause. Changing the location of the clause resulted in a large number of errors. There were a greater number of errors in order and a larger number of subjects starting twice in the syntactic condition than in the semantic condition.

When the sentence is fluent, such as SAAD or Negative, syntactic structure is pre-programmed and automatic after the sentence is once begun. The exception would be the selection of the more difficult or alternative schema which in this case is the Passive. A confounding factor, however, is the proficiency of the individual in the use of the Passive.

Allocation of Pausing Time

Goldman-Eisler (1968) has suggested that pausing may be withheld or redistributed in accordance with the needs of the individual. The amount of pausing to speaking and the individual speech rate are subject to wide individual variance. Whether the rate is individually stable across tasks is conjectural.

It is apparent from the analysis of the speech to pause ratio that under normal conditions of fluent speaking, a minimal amount of pausing will occur since all the related functional systems are under control and skillfully interwoven. The data indicated, however, that the 30% ratio of pausing to speaking which was found by Henderson (1965) occurs in this data with discrete linguistic units rather than discursive material. There may be a constant ratio which is

exceeded whenever cognitive activity increases, since a shift of attention occurs and the result is asynchrony in the integration of the various systems.

The individual is able to reallocate pausing, including respiratory pauses, at will to accommodate demands of the task. The summary of the data indicates that in the Initial Pause condition there was a significant increase in the ratio after the semantic task, suggesting the effortful and creative aspects of semantic abstraction and formulation.

Unfortunately, the measures in the pausing were not comparable on a one-to-one basis. Recent studies in developmental aspects of pausing, however, also tend to support the contention that as fluency and efficiency increase, pausing decreases. Kowal et al. (1975) measured pausing of different age groups of children and concluded that pausing decreases with age and greater proficiency with the language. Unquestionably, measuring isolated pauses such as those at syntactic junctures will not reveal depth or nature of cognitive activity.

Sequential Versus Simultaneous Processing

Without a more specific and disruptive result in either interruption location, the order of processing remains primarily conjectural.

It is obvious, however, that both occur depending on the efficiency of the language skills of the individual and the difficulty of the cognitive operations involved. In fluent, well-practicedspeech, where neither the semantic planning nor the syntactic structure is difficult or new, both processes may be simultaneously carried out so skillfully that little or no hesitation is detected. Where difficult semantic content is being formulated, but it is being carried out in well-used syntactic forms, pauses before the sentence would reflect semantic planning, but the syntactic program would be automatic since it required no change. In cases where both are difficult, longer hesitations would occur prior to the sentence for semantic planning, and for assembling the different syntactic structure. During the sentence, monitoring of temporal order of words would be evident since in this case both operations would be under central control, and the asynchrony exhibited by such control would be evident.

The data in this research strongly support anticipatory planning prior to verbalization, but do not furnish the specific and selective disruption which would identify the order of processing.

Summary

The data in this research clearly support a conclusion that cognitive planning occurs prior to verbalization. The exact nature and sequence of the processing has not been clarified, although several of the analyses strongly suggest that semantic planning not only occurs prior to verbalization but significantly affects pausing before the verbalization. Since there were few errors and no specific and selective interference with either task or transformations, no definitive statement can be made. The lack of interference in sentences after the syntactic task supports Goldman-Eisler's assumption that syntactic structures are pre-programmed inasmuch as verbalization once begun was not disrupted by the interpolation of the secondary task.

Toward a Theory of Speech Production

It appears likely that two levels of processing exist for both semantic formulation and syntactic ordering. Conception of content or semantic planning is effortful and requires the attention and allocation of central capacity, while lexical choice is primarily on the level of execution with selections made from accessible, well-used words in long-term memory.

At the central cognitive level, there must be semantic analysis and content formulation, planning and direction of neural commands to articulatory muscles, interweaving of respiratory behavior, and ongoing syntactic corrections based on auditory feedback.

If no change is needed in either system, semantic or syntactic, and they are fluent, the two processes may coexist. However, if both processes required decision making, then they must be processed sequentially. In this case, syntactic ordering which is primarily based on motor program sequences would occur serially and be responsive to the semantic content.

The interpolated secondary task method used in this research appears to be a useful technique to explore relationships between task difficulty and level of processing. With more careful analysis of task requirements, a further differentiation between semantic and syntactic processing might be possible in subsequent research.

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Table 1

Task Durations (Seconds)--Means and Standard Deviations For Significant Effects

	Initial Pause	Within Sentence	Row Means
Tasks			
Semantic	6.40 (1.61)	4.89 (1.15)	5.64 (1.58)
Syntactic	8.15 (1.88)	7.23 (1.73)	7.69 (1.86)
Control	3.96 (1.17)	2.96 (1.20)	3.46 (1.28)
Column Mean	6.17 (1.55)	5.03 (1.76)	
Transformations			
SAAD	5.99 (2.32)	4.94 (2.18)	5.47 (2.25)
Negative	6.12 (2.28)	4.97 (2.28)	5.55 (2.28)
Passive	6.39 (2.41)	5.17 (2.24)	5.78 (2.33)
Column Mean	6.17 (2.33)	5.03 (2.22)	

NOTE. Standard deviations are presented within parentheses.

Table 2

Task Durations in Seconds--Means and Standard Deviations for Significant Effects--Transformations Within Tasks

Task	Transformation	Mean (sd)
Semantic	SAAD	5.33 (1.36)
	Negative	5.54 (1.68)
	Passive	6.07 (1.64)
Syntactic	SAAD	7.60 (1.99)
	Negative	7.70 (1.67)
	Passive	7.77 (1.93)
Control	SAAD	3.48 (1.29)
	Negative	3.40 (1.29)
	Passive	3.50 (1.28)

Table 3

Means and Standard Deviations for Tasks Within Location (Pausing Time: Seconds)

Task	Initial Pause	Within Sentence	Row Means
Semantic	3.02 (1.76)	1.67 (0.95)	2.35 (1.36)
Syntactic	2.69 (1.70)	1.78 (1.41)	2.24 (1.56)
Control	2.00 (1.56)	1.12 (0.49)	1.56 (0.85)
Column Means	2.57 (1.56)	1.52 (0.95)	

NOTE. Standard deviations are presented within parentheses.

Table 4

Means and Standard Deviations for Transformations Within Location (Pausing Time: Seconds)

Transformations	Initial Pause	Within Sentence	Row Means
SAAD	2.33 (1.55)	1.40 (0.70)	1.87 (1.13)
Negative	2.39 (1.42)	1.63 (1.44)	2.01 (1.43)
Passive	3.00 (1.82)	1.54 (0.89)	2.27 (1.36)
Column Means	2.57 (1.60)	1.52 (1.01)	

NOTE. Standard deviations are presented within parentheses.

Table 5

P/P+V Ratios for Tasks

Tasks	Initial Pause Mean	(Arcsin)	Within Sentence Mean	(Arcsin)
Semantic	.40	(1.35)	.37	(1.30)
Syntactic	.38	(1.31)	.38	(1.32)
Control	.31	(1.17)	.82	(1.20)

Table 6

P/P+V Ratios for Tasks (Arcsin Transformations)

Tasks	Initial Pause	Within Sentence
Semantic	1.35 (.24)	1.30 (.23)
Syntactic	1.31 (.26)	1.32 (.26)
Control	1.17 (.22)	1.20 (.16)

NOTE. Standard deviations are presented within parentheses.

Table 7

Error Frequency: Grouped by Tasks

Error	Semantic	Syntactic
Transformation		
1. Wrong or none	36	21
Omissions		
2. Clause	5	4
3. Word	29	35
Order		
4. Entire clause	14	8
5. Word (adjective or noun	14	28
6. Syntactic	0	5
Meaning		
7. Different word with same meaning	29	36
8. Collapsed clause	6	4
9. Error in semantic task	4	0
Memory		
10. Forgot original sentence	9	6
11. Forgot instruction	0	0
Two Starts		
12. After interruption	31	35
13. Before interruption	7	19
Total	184 (05%)	201 (06%)

Table 8

Error Frequency: Grouped by Interruption Location

Errors	Initial Pause				Within Sentence			
Transformation	SAAD	Negative	Passive	Total	SAAD	Negative	Passive	Total
Transformation								
1. Wrong or none	5	10	22	37	1	8	12	21
Omissions								
2. Clause	1	0	3	4	3	1	1	5
3. Word	12	10	25	47	7	8	2	17
Order								
4. Entire clause	2	2	10	14	4	4	0	8
5. Word (adjective or noun)	8	3	2	13	12	5	12	29
6. Syntactic task	0	1	1	2	0	2	1	3
Meaning								
7. Different word with same meaning	9	21	13	43	8	4	10	22
8. Collapsed clause	1	2	3	6	1	1	2	4
9. Error in semantic task	1	0	1	2	1	0	1	2
Memory								
10. Forgot original sentence	5	0	6	11	1	1	2	4
11. Forgot instruction	0	0	0	0	0	0	0	0

Table 8 (Cont.)

Errors	Initial Pause				Within Sentence			
Transformation	SAAD	Negative	Passive	Total	SAAD	Negative	Passive	Total
Two Starts								
12. After interruption	10	10	18	38	8	5	15	28
13. Before interruption	0	0	0	0	5	9	12	26
Total	54	59	104	217	51	48	69	168